Application of Cold-formed Steel in Foundations

Andrew S. Zakrzewski

APPLICATION OF COLD-FORMED STEEL IN FOUNDATIONS

by

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SUMMARY

The paper describes the application of cold-formed steel in house basements. It also points out that a large market potential exists for steel foundations to be applied to Preengineered Buildings and Mobile Homes.

Experience gained during the last four years in building test structures and two experimental basements is discussed and suggestions made about the future design possibilities.

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APPLICATION OF COLD-FORMED STEEL IN FOUNDATIONS

1. INTRODUCTION

For centuries, field stone and heavy timber piling were the principle materials from which foundations were built. After the invention of cement, concrete, reinforced concrete and concrete blocks took over with heavy steel sections replacing timber piling.

Only recently, attempts have been made to replace the "wet" cement foundations with a dry-constructed system.

Three dry systems have so far been tried out; namely, in order of their appearance:

- treated wood system,
- precast concrete system,
- panelized steel wall system.

While the concept of cold-formed steel foundations can be applied in all low-rise buildings, preengineered industrial or commercial buildings and mobile homes, we will concentrate, in this paper, mainly on the application in house basements. This is possibly the most difficult application both from economic justification and technological points of view. It is also the only application where some practical experience has so far been gathered.

In a 1973 article entitled "Improved Foundation Design", W.M. McCance, P. Eng., HUDAC's Director of Research explained the reasons why new, dry basement systems are required and cited some statistics of structural failures in traditionally designed basements. Excerpts from this article are given in Appendix A.

Until recently, steel was not considered a suitable and competitive material in this area. I must admit that our company almost stumbled by accident on this application. And yet, if one thinks about it, steel should be able to compete; after all, it generally beats wood and concrete when it comes to prefabrication. It assures great exactness, very high strength-to-weight ratio, low coefficient of thermal expansion, and imperviousness to rodents and vermin.

In 1971, our company designed a steel basement for an experimental house in Regina, Saskatchewan using standard Westeel-Rosco steel panels. (See Figures 1 to 4) This basement was built from very heavy fluted profiles to withstand exceptionally heavy soil pressure encountered in the so-called "active soil" areas of Western Canada. This basement is a part of the Mark IX Experimental House built by the Housing and Urban Development Association of Canada (HUDAC). It is a three bedroom split level with 1,650 sq. ft. finished floor area and a 624 sq. ft. basement area.

In 1973, we particpated in the design and building of another HUDAC Experimental House, Mark X, located in Guelph, Ontario. The raised bungalow has an area of 864 sq. ft. on each level (lower level and upper level). This time we wanted to find out whether a steel-made basement could economically compete with other basement systems in a typical raised bungalow, under normal soil conditions. (See Figures 5 to 9).

In this second application, we paid special attention to corrosion problems and after a series of tests, installed in the summer of 1974 a cathodic protection system.

To continue corrosion studies, we built, early this year on our premises, a small (12' x 24') Research Basement (See Figures 10 and 11) where the effect of various steel finishes, various soils and various current densities for cathodic protection are being studied.

Next year, we plan to build our own experimental house which will be fully instrumented and serve as a long term laboratory for testing the performance of various steel components. (See Figure 12) The house will include a steel basement and we hope to incorporate in it a variety of design concepts we have developed from our experience with the previous basements.

2. WHY STEEL BASEMENTS?

The "dry" basement systems were developed in response to changes in the market requirements:

1. The dry systems reduce the on-site work, and thus help to overcome the shortage of on-site labour which is also generally more expensive than factory labour.

2. The dry system eliminates, or at least greatly reduces, the "wet and dirty" work. The erection can be carried out even during cold or wet weather.

3. The reduction of on-site work and greater insensitivity to weather reduces the erection time of houses and thus the cost of financing.

4. Good dry systems can be free from cracking and are of uniform quality.

Wood basements were first developed in Canada in the early 60's and after the usual gestation period became quite popular in the U.S.A. and more recently in Western Canada. Several thousands have sc far been built. Figure 13 shows a typical cross-section.

3. DESIGN

The discussion of various design aspects of steel basements may be divided as follows:

- (i) Gravel Pad
- (ii) Footings
- (iii) Structural Aspects
- (iv) Ease of Erection
- (v) Protection Against Corrosion
- (vi) Heat Energy Conservation
- (vii) Thermal Bridging and Condensation
- (viii) Safety Aspects (Electrical and Fire Protection)
- (ix) Aesthetics

(i) Gravel Pad

The traditional basement construction begins with a wet-placed footing which serves as a construction leveller and final load spreader. The "all dry" approach must rely on a dry-placed interface or it looses the advantages of one-day, all season construction. The gravel pad (originally devised in the U.S.A. to correct drainage and leakage problems in traditional types of basements) fits the job nicely.

The gravel pad provides levelling, load spreading and an overall drainage path all in one (see Figure 14). It does away with the traditional reliance on separate drainage tiles.

The experience gained with a few thousand dry system basements on this continent suggests that the gravel pad performs the drainage function very well.

The floor/wall joints in steel basements are not tight. Nor should they be in any basement system; if the drainage system fails or the water table rises,for whatever reason, several inches above the basement floor level, we want it to leak into the basement. Otherwise, the basement floor could rupture and the walls could also be damaged.

(ii) Footings

Footings used in connection with a gravel pad are made from between .105" and .135"thick steel in a form of a Z, or modified Z section.

Footings are placed on top of the gravel pad along the whole periphery of the house and in the next stage of erection the basement walls are placed on the top of the footings.

Without the massive concrete foundation, the total weight that the soil must support is considerably smaller. Consequently, the width of the footing can be reduced; 4" wide footings are more than sufficient in most cases. Figure 15 shows how the gravel pad spreads the load.

In addition to transferring the load from the walls to the gravel pad, the footing can also serve as screed for the concrete basement floor. The shape of the footing depends upon the design of the basement floor: if the floor is a suspended steel floor or a concrete floor poured prior to backfilling operation, then the footings have to withstand very small lateral forces. If, on the other hand, no basement floor exists at the time of backfilling, then the footings are temporarily subjected to considerable bending moments caused by the backfill pressure and later the normal soil pressure. Lateral reinforcing connections (see Figure 5) are then required.

(iii) Structural Aspects

The basement walls are basically stressed by house weight, by live loads and by soil pressure.

Figure 15 shows the assumed loads in the previously mentioned HUDAC "Mark X" Experimental House. The steel basement walls can of course be designed to suit any other house type and layout.

The maximum bending moment due to soil pressure depends upon the amount of pressure its distribution and the depth of the basement wall below the ground level. The soil pressure depends upon the type of soil and changes in its content of moisture. The soil pressure is lowest in a very permeable soil, heaviest in so-called "active soils" which swell in winter by accepting moisture and may exert pressures several times larger than those of normal soils. (See Figure 16)

The accepted usage on this continent for shallow foundations (e.g., house basements) located in normal soil assumes a soil pressure equal to half the hydrostatic pressure. Figure 17 shows the assumed triangular distribution and the value of the maximum bending moment.

Our first steel basement (HUDAC Mark IX) was built from standard Westeel-Rosco T-30 roof deck material,.060" thick with G-90 galvanized finish. The panels were 18" wide and each panel had four 3" deep ribs.

Our second steel basement (HUDAC Mark X) was built from standard Armco panels. The steel was .030" thick with G-90 galvanized finish. The panels were 8' high and 18" wide with 3" deep ribs at either end of the panel (see Figure 18).

Obviously, if the basement was fully submerged below the ground, the total moment would have been four times larger and consequently, heavier panels would have to be used. Steel can best compete with other materials, particularly with concrete in partially raised basements. Fortunately, the tendency towards utilization of insulated basements as living quarters supports the raised basement concept.

The stresses encountered in panel ribs under the above mentioned load assumptions are shown in Figure 18. The panel deflection, particularly in panels' flat section, is objectionable for visual reasons in the portion protruding above the ground. It can be reduced by stiffening the panel by means of either horizontal or vertical ribs (see Figure 19a and 19b). As the panel is relatively narrow, the horizontal ribs have a greater stiffening effect but may give "handle" for freezing ground to lift the panel.)

Another method tried successfully is to stiffen the panel on the interior side with an independent stiffener (or stiffeners) locked between the panel ribs (see Figure 19c).

We are presently looking into yet another solution: splitting the wall panels into specially designed load bearing studs and very simple panels, edges of which would wedge into the corresponding crevices in studs during the erection. Such design might prove beneficial for a number of reasons:

1. The walls would be even easier to install, particularly in high wind.
2. The studs could be perforated thus creating better "thermal studs", i.e., further reducing the heat transfer.
3. Panels could be easily exchanged in case of damage.

(iv) Ease of Erection

The combination of gravel pad, precise steel footings and light, precise steel panels allows simple and fast erection (see Figure 20). Independent time studies suggest that two pairs of experienced erectors could erect the basement of a 24' x 36' house in under five hours, beginning with spreading and levelling of gravel. If 24" wide rather than 16" wide panels were used, the elapsed time would be reduced by one hour for a total of 15 man hours. About 70 man hours are required to erect a concrete basement using prefabricated form work. Because of the wet construction and the separate form-cure-strip operations for both footings and wall, the concrete basement takes three to four days even in good weather.

The steel basement requires no mechanical handling, heavy equipment, or special tools. It brings back the advantage of man handling flexibility: access to any site. It is particularly advantageous in remote areas, scattered lots and single house jobs.

The jack columns supporting the main floor beam (see Figures 21 and 22) are placed on steel footing plates on the gravel pad. Where the design calls for internal walls, they can be made load bearing and thus can replace the jack columns. The internal load bearing walls would be supported by a strip footing plate similar to the peripheral footing.

(v) Corrosion

Virtually nothing can be found in the literature that is directly applicable to underground corrosion of load bearing steel footings or walls made from light gauge steel. This is the case because the corrosivity of soil varies tremendously depending on its composition. Also, the duration of the test must be in the order of several years to obtain meaningful results.

Data is available on buried steel tanks and culverts which is in part helpful. However, these structures are not as affected by changing soil pressure, temperature differential and soil with varying water and oxygen levels, as steel foundations.

Corrosion protection of steel in soil falls into four methods:

1. A barrier coating (i.e., coal tar epoxies).
2. A sacrificial coating (i.e., hot dip galvanized).
3. Cathodic protection using impressed current (i.e., a d.c. rectifier and an inert anode such as graphite).
4. Cathodic protection using sacrifical anodes (i.e., a magnesium anode).

Often, coatings and cathodic protection are combined to compliment each other and thus to provide the maximal corrosion protection.

Specific areas of concern with steel basement corrosion protection are:

1. The protection system must be inexpensive; otherwise, the steel basement will not be cost-competitive with conventional basements.
2. To ensure high, uniform quality of corrosion protection, as little work as possible should be carried out on site.
3. Because the basement walls often protrude above ground, the factory-applied protective coating must be aesthetically pleasing and provide not only protection underground but also protection against atmospheric corrosion and abrasion.

We recently built a Research Basement for the evaulation of various methods against corrosion of steel basement walls. Nine types of panel coatings are being tested. There are six environments under study for each type of panel, including special backfills and cathodic protection. The heat and humidity inside the Research Basement are being controlled to simulate actual conditons of a lived-in house.

A simplified schematic diagram describing the creation of a corrosion cell is shown in Figure 23. The principle of the protecting action of an active (impressed current) cathodic protection system is also shown in Figure 23 .

The tests so far carried out by ourselves using both active and passive cathodic protection are very encouraging. In an active system, only a fraction of an ampere at 24 volts is required so that the cost of power amounts to only between one and two dollars per year per house.

Another section of the current research program involves determination of the optimal anode-to-basement geometry in the application of cathodic protection. The aim is to obtain a uniform polarized potential along the whole periphery of the basement walls with a minimum number of anodes.

Probably the most critical area of concern in corrosion protection of steel basements is the possibility of crevice corrosion. Steel basement walls consist of vertical interlocking steel panels. The interface of two adjacent panels creates a crevice. The problems of adequate protection of such crevices must be thoroughly studied and solved.

In the Mark X Experimental Basement, a bead of special caulking was factory-applied prior to erection and this provided a water tight seal on interlocking. We are attempting to determine whether such sealants can eliminate the problem of crevice corrosion.

(vi) Heat Energy Conservation

Studies underway in Canada indicate that the winter heat loss through the basement of a typical bungalow amounts to about 29% of the total house heat loss.

In an 8,000 degree day climate, a bungalow dissipates during one heating season, 28 million BTU's. This is equivalent to 225 imperial gallons of fuel oil.*

* One imperial gallon equals 1.2 U.S. gallon.

A steel wall basement system similar to the one used in the Mark X Experimental House provides ample space for top to bottom insulation. The heat loss per heating season could thus be reduced to 10.2 million BTU's at a total saving of 143 imperial gallons of oil per season.

The use of well insulated raised basements results in a further indirect heat loss reduction: On the average, the raised basements houses loose 13% less heat than bungalows because less wall area above ground is required to provide the same living space.

(vii) Thermal Bridging and Condensation

Traditional poured concrete or block foundations present a surface of low but uniform temperature to the inside of the enclosure.

The steel systems examined to date have been light gauge, formed panels with interlocking ribs for structural stability. The spaces between these ribs are insulated and so the ribs themselves bridge the insulation and provide a direct path for heat to flow between the inside and the outside of the house.

Heat loss is not considered to be of critical concern because the cross section of the web portion of the bridging element is relatively small. However, the high thermal conductivity of steel results in a local temperature depression along the lines of contact between the steel ribs and the inner sheathing.

Experience has shown that if a temperature gradient across the room side surface of the wall sheathing exceeds 4 degrees F, the dust will settle on the colder areas , a phenomenon called "ghosting".

In our two experimental basements, we tried to avoid thermal bridging in the following manner: In the Mark IX, the 1" thick rigid board insulation was attached to the outside of the basement panels with nylon pins and after they were sheared off by the heaving action of the soil, with adhesives (see Figure 24). This exterior insulation eliminated thermal bridging.

Exterior insulation, placed below ground, is susceptible to physical damage during backfilling , damage and dislocation caused by the heaving soil as well as deterioration from the environment. The cost of rigid insulation and its attachment by means of adhesives is high.

We are monitoring the temperature gradients in the Mark IX basement walls and watching for any signs of dislocation or deterioration.

Two insulating materials were used in the Mark X. All but a 12' section of basement wall was insulated with spray-on polyurethane foam on the entire inner surface to an average thickness of 1". This resulted in an R-7 insulating value (see Figure 25). This insulation provided an effective covering and eliminated any cold areas on which moisture could condense. Hence, no additional vapour barrier was required.

Horizontal steel furring channels were fastened to the panel ribs to facilitate the attachment of the inside sheathing board.

The remaining 12' section of wall was insulated with fiberglass friction-fit batts placed between the panel ribs in the conventional manner (see Figure 26). A polyethylene vapour barrier was installed over the insulation to prevent moisture from penetrating the insulation, condensing on the steel panel and then dampening the insulation. Horizontal furring channels as described above were also used in this case.

Because the furring strips eliminate a direct contact between the gypsum board and the basement wall ribs, the thermal bridging is virtually non-existent.

Insulation with fiberglass is considerably less expensive than the use of the on-site sprayed foam. We are monitoring the behaviour and performance of both types of insulation in order to determine their relative value.

(vii) Safety Aspects (Electricals and Fire Protection)

The extensive contact between the basement steel wall panels, the steel footing and the ground renders the whole basement structure electrically grounded. This remains true even if the panels are heavily coated on one side, provided they are solidly bolted to each other and to the footing. We are jointly with the Ontario Hydro, monitoring the quality of grounding in the Mark X Experimental House to make sure that it does not deteriorate in time.

If steel is also used in framing of the main floor (as it was in the case of the Mark X) and if the upper structure is suitably connected to the basement, then the whole house might be considered as electrically "fully bonded".

A fully bonded house eliminates any danger of electrocution by accidental damage of an energized conductor.

In Canada, steel-framed houses may be wired using unarmoured (plastic insulated) conductors but such conductors must not be in contact with steel. This is achieved by providing plastic bushing whenever the conductor has to penetrate a steel component and by keeping the conductor away from steel studs or joists by plastic stand-off clips.

If the whole steel framing is grounded, such costly precautions become unnecessary.

Where no in-house water piping exists (e.g., cottages) or plastic pipes are used for the water and/or gas supply, ground rods are used for grounding of appliances. Again, ground rods become redundant if the steel framing is grounded.

It is also possible that the three-wire electric distribution system universally used in houses will be replaced in fully-bonded and grounded houses by a two-wire system. Each receptacle could be grounded simply by a suitable attachment to a structural steel element.

The existing codes do not specify any fire resistance rating for walls in detached houses. A 15 minute fire resistance rating is now under consideration in the United States as well as in Canada.

An application of 1/2" thick bypsum board on the room side of steel studs will provide a 25 minute fire resistance rating.

The Canadian Code states that the party walls in multiple occupancy low-rise buildings (semi-detached, duplexes, townhouses, etc.) total area of which at grade level does not exceed 6,000 sq. ft. must have a 2 hour rating. In such cases, the party walls between the individual units (e.g., between two adjacent townhouses) might, for instance, consist of two separate steel-framed walls, each sheathed on both sides with 5/8" gypsum board and separated by a small air space.

All these regulations apply to the basement walls as well as to the upper floors' walls.

(ix) Aesthetics

When discussing the requirements for protective coatings on steel panels, the "pleasing appearance" of such a coating has already been mentioned.

For instance, a use of stucco-type coating (made more elastic by an addition of an elastomer) would look better than the parging finish normally applied to both block and poured concrete foundations.

The exposed portion of basement walls could of course be covered by any conventional cladding but in most cases, this would unnecessarily increase the cost.

Architects might want to consider the use of embossed or textured steel for basement panels. Such treatment could add to the aesthetic appeal of the house exterior.

The interior finish of the steel basement would be identical to that of any conventional finished basement.

4. ECONOMICS AND POTENTIAL MARKETS

As it is the case with practically every application of steel in houses or preengineered buildings, one should not compare the costs of steel with the cost of other materials, or even the cost of finished components. The cost of the erected structure is a better criterium.

(i) Basements for Houses

After completion of the Mark X Experimental House, we made an attempt to compare the cost of a steel-made basement with costs of other basement systems. Since the costs of systems using concrete are greatly dependent on the local price of concrete, their prices were plotted as a function of concrete prices per cubic yard. The results are shown in Figure 27 .

As the development is incomplete and our experience is very limited, the cost estimates are tentative only. This is reflected in Figure 27 , in the wide band of costs. Figure 27 confirms that the steel basements are economically feasible, particularly when one takes into consideration other advantages of such a system; the speed of erection, the greater independence from weather, the lower cost of transportation and, above all, the dimensional exactness, dimensional stability and freedom from recalls caused by cracks, leaks, etc. With the advent of builders' warranties,this last point might be a decisive one as far as builders are concerned.

A list of advantages of steel basement systems over other systems was compiled in Figure 28.

The potential market for basements in Canada and the U.S.A.

for 1980 is shown in Figure 29. No attempt has been made at this time to estimate the degree of market penetration by steel, but the potential tonnage is huge when one realizes that 1-1/2 ton of steel was used on the Mark X for the basement footing system and basement walls.

(ii) Load Bearing Skirtings and Basements for Mobile Homes

As Figure 30 shows, mobile homes represent a very sizable sector of the total housing market.

Mobile homes slowly evolve into prefabricated modular houses; the advent of the so-called "double wides" finally destroyed the pretension that mobile homes are really "houses on wheels" which can easily and speedily be moved at any time after the initial erection.

A sectional steel basement could be transported to the site together with, possibly even in, the mobile home.

While most mobile homes are still made from wood, a trend to convert to steel is noticeable. Our company has already contributed to this trend by introducing steel roof bows and steel sub-frames combined with steel floor joists. Such steel frames could be fabricated to very exact dimensions, and thus could be easily and exactly placed on top of prefabricated steel skirts or basements.

A basement or crawl space could eliminate the acute shortage of storage space in mobile homes.

The fact that a steel basement could be relatively easily dug out and reused at another location is of some importance in the case of mobile homes.

(iii) Preengineered Buildings

As Figure 31 shows, the demand for preengineered buildings in the United States has grown rapidly and continuously over the last two decades. The picture is similar in Canada.

Just because the preengineered buildings are made almost exclusively from steel, the chances for introduction of steel footings and steel load bearing skirts are good. The manufacturers of preengineered buildings have the necessary know-how and facilities to manufacture such items.

CONCLUSIONS

The so-called "Dry Foundation Systems" are becoming increasingly popular because of their short erection time and greater freedom from weather conditions.

The demand for dry foundation systems has opened up a new field for the application of cold-formed steel. Foundations must perform a variety of functions which are quite different to those performed by structural elements above ground. Consequently, new design solutions for steel components have to be developed.

Adequate and yet economically feasible protection against corrosion below ground is one of the major problems to be solved.

Appendix (A) Excerpts from an article on 'Improved Foundation Design' written in 1973 by W.M. McCance, P.Eng., HUDAC Director of Research.

"The majority of Canadian houses are built with basements. Our climate, together with the fact that the furnace and the fuel supply were traditionally located in the cellar, probably accounts for this preference on the part of most home owners. In any event, since the house has to have a foundation of some sort, a full basement is not much more expensive and besides, provides the greatest volume of contained space for the price.

With land costs becoming a major factor in the total cost of housing, smaller lots and more compact dwelling types, such as the two-storey house, have gained in popularity. The space beneath the house has assumed new importance as a habitable area. It is too valuable to be overlooked and can no longer simply be regarded as a storage area, a furnace room, a laundry or just an out-of-the-way place for the children to play on rainy days.

The familiar cellar, with its low ceiling, small windows, often damp walls and floors has given way to a demand for space which approaches the livability of other parts of the house above ground. The split-entrance house and the split-level plan are two attempts to lift the foundation out of the earth and allow it to assume the characteristics and usefulness of the rest of the house.

This change in use has not, however, generally been accompanied by a change in the traditional use of materials and methods formerly appropriate for ordinary basements. Foundation wall construction which was adequate before, is often no longer so. The quality and workmanship of concrete and concrete block walls is now subject to critical appraisal and is proving to be unsatisfactory for the new uses demanded of them.

The HUDAC Technical Research Committee recognized some years ago that walls which regularly cracked, developed leaks and were hard to insulate and convert to finished living areas were not acceptable.

This view has recently been substantiated by a survey of Canadian builders conducted for HUDAC by Urwick, Currie and Partners Limited in connection with their study of a warranty and insurance protection plan being considered for new home owners. This management consulting firm circulated a questionnaire to some 2,036 HUDAC builder members and received a 12.4% reply.

One of the questions asked was "OF THE VALID COMPLAINTS REGARDING MAJOR STRUCTURAL DEFECTS WHICH YOU RECEIVED FROM HOME PURCHASERS, HOW MANY FELL INTO EACH OF THE FOLLOWING CATEGORIES?" The answers received were as follows:

Item	Number	Per Cent of Total
Basement Wall Defects	464	48.7%
Floor Defects	170	17.8
Walls and Framing Defects	122	12.8
Roof Structure Defects	74	7.8
Foundation Subsidence	35	3.7
Other	88	9.2
TOTAL	953	100.0%

Almost half the major structural defects customers complained to their builders about, had to do with basement walls.

The Research Foundation of the National Association of Home Builders in the United States looked into basement water leakage problems a few years ago and reported that 85% of builders responding to a survey said that they now have or have had leakage problems. Three-fourths of all leakage reported, occurred within the first six months after construction was completed. This survey indicated heavy leakage occurred just as often with poured concrete walls as with masonry block walls."

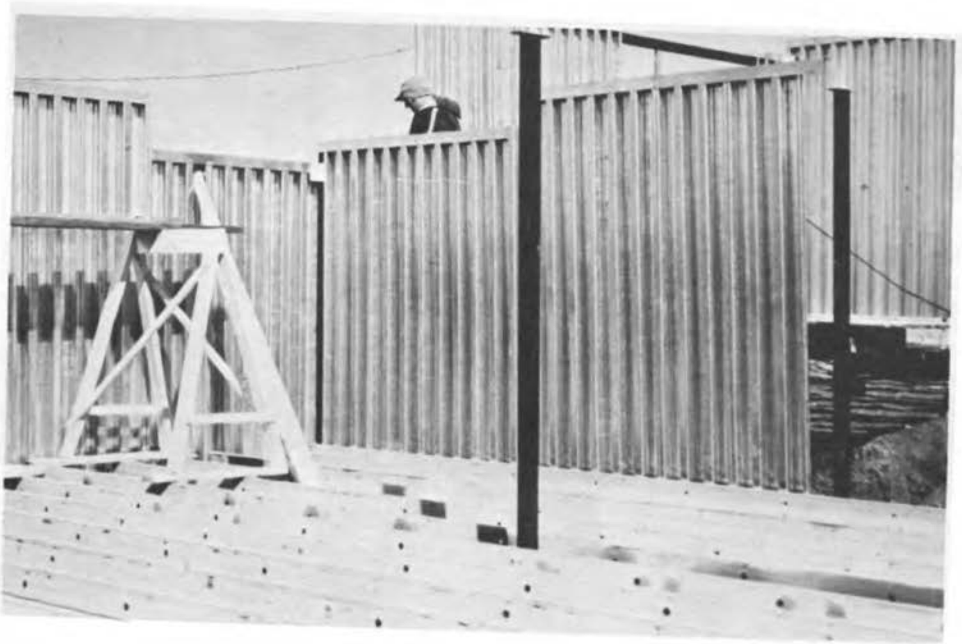


FIGURE 1 - MARK IX SUSPENDED BASEMENT FLOOR JOISTS

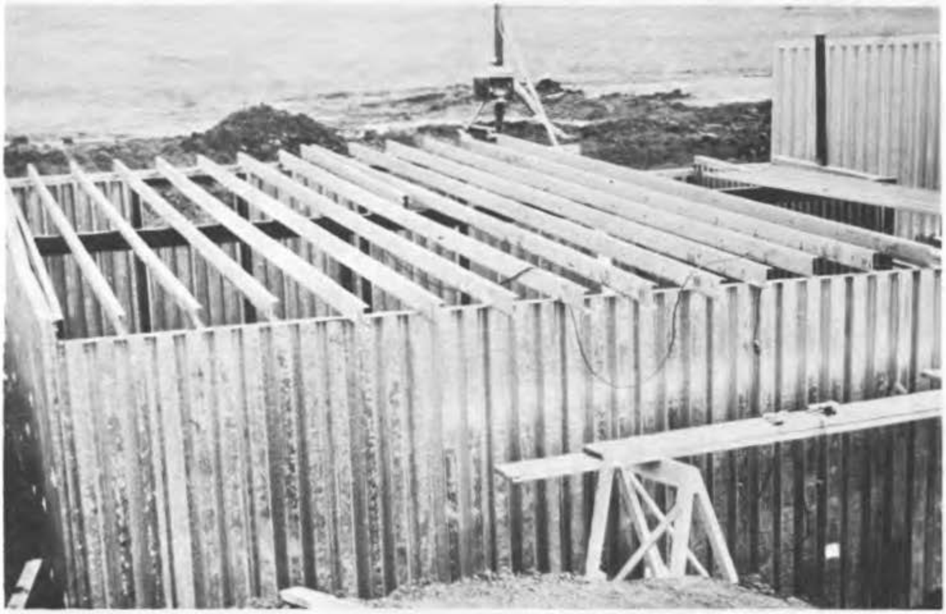


FIGURE 2 - MARK IX BASEMENT PANELS AND MAIN FLOOR JOISTS

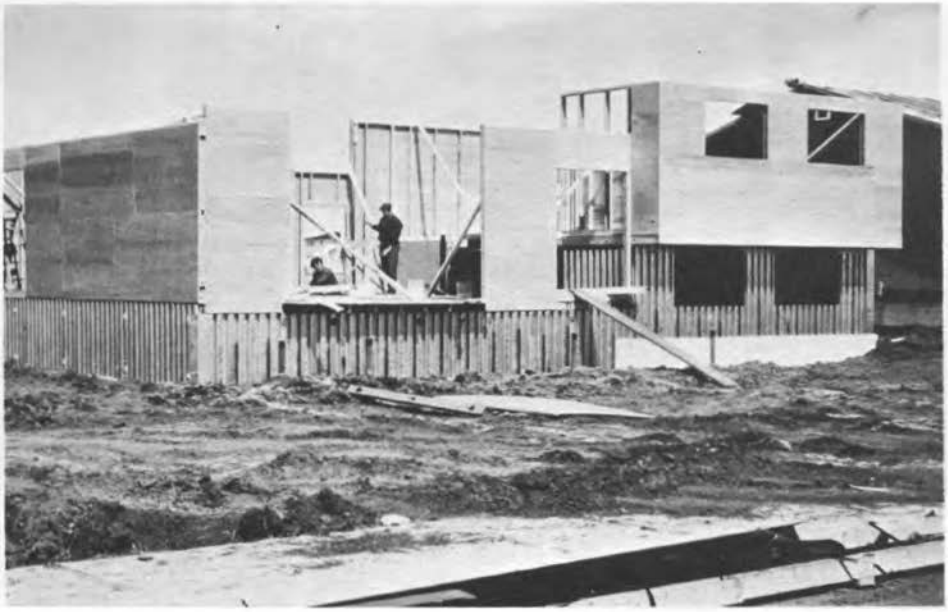


FIGURE 3 - MARK IX UPPER WALL CONSTRUCTION

FIGURE 4 - MARK IX FINISHED HOUSE

FIGURE 5 - MARK X FOOTING ASSEMBLY ON GRAVEL PAD

FIGURE 6 - MARK X BASEMENT PANEL ERECTION

FIGURE 7 - MARK X TOP CHANNEL ASSEMBLY

FIGURE 8 - MARK X MAIN FLOOR PANEL ERECTION

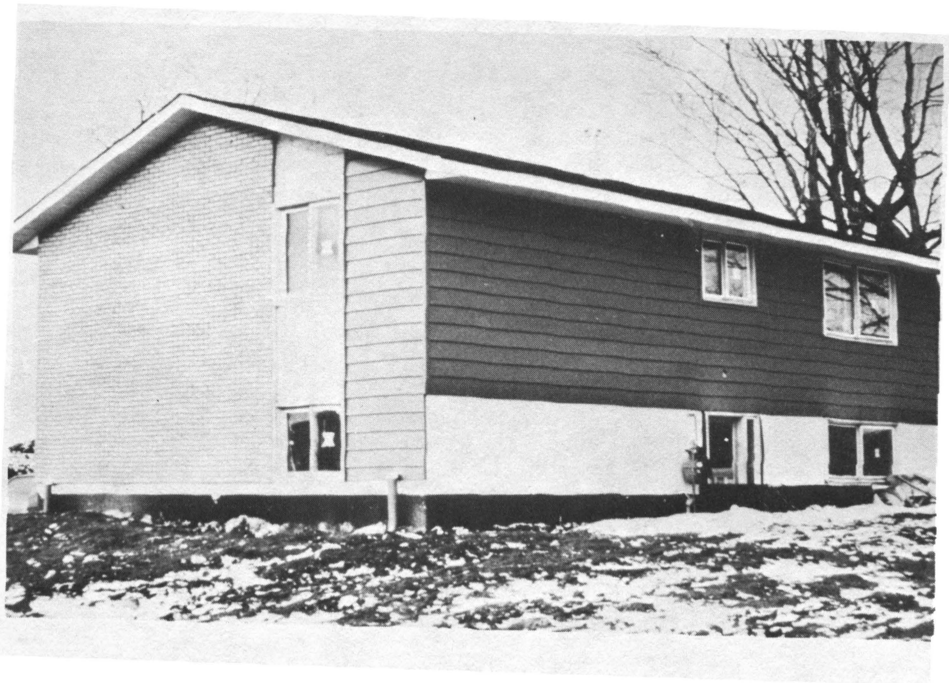


FIGURE 9 - MARK X FINISHED HOUSE (REAR VIEW)

FIGURE 10 - DOFASCO RESEARCH BASEMENT (EXTERIOR)

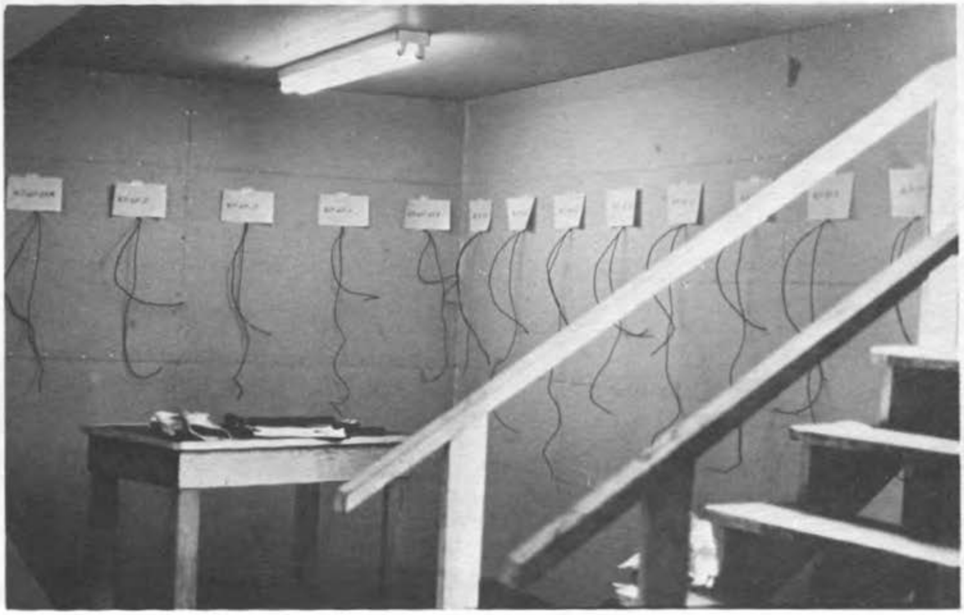


FIGURE 11 - DOFASCO RESEARCH BASEMENT (INTERIOR)

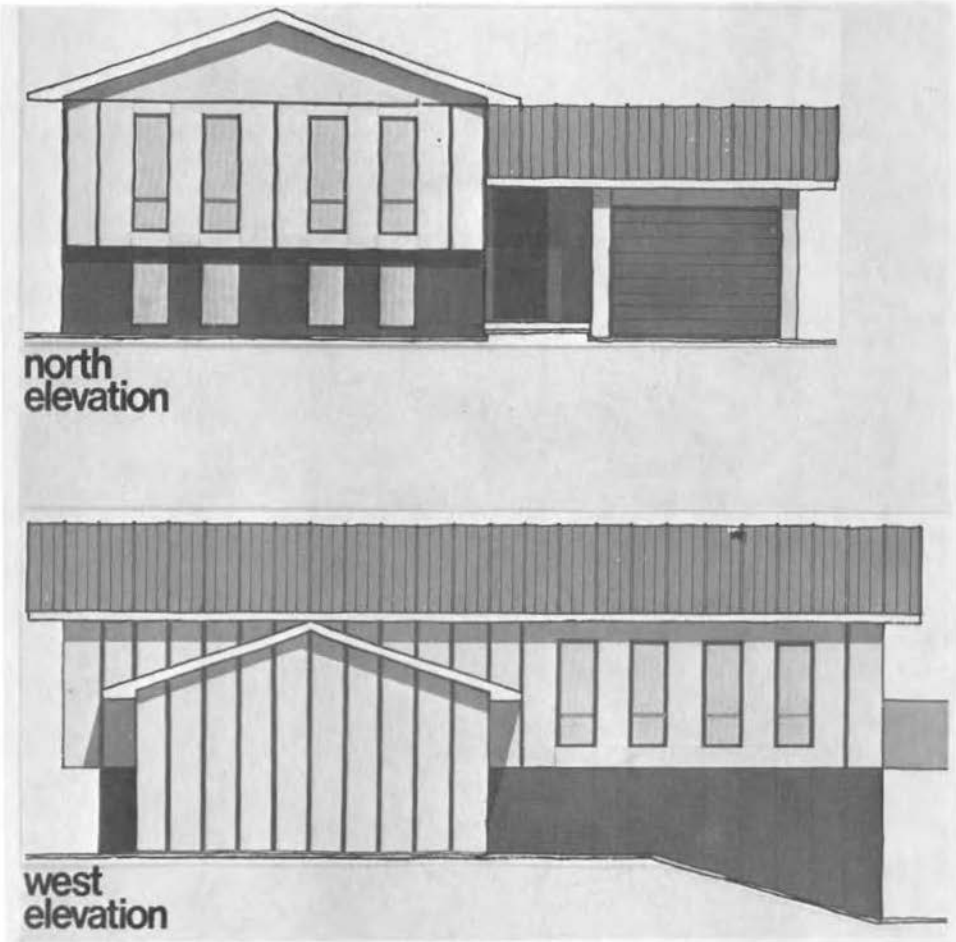


FIGURE 12 - DOFASCO PROPOSED EXPERIMENTAL HOUSE

FIGURE 13. PRESERVATIVE TREATED WOOD FOR SUSPENDED WOOD FLOOR BASEMENT

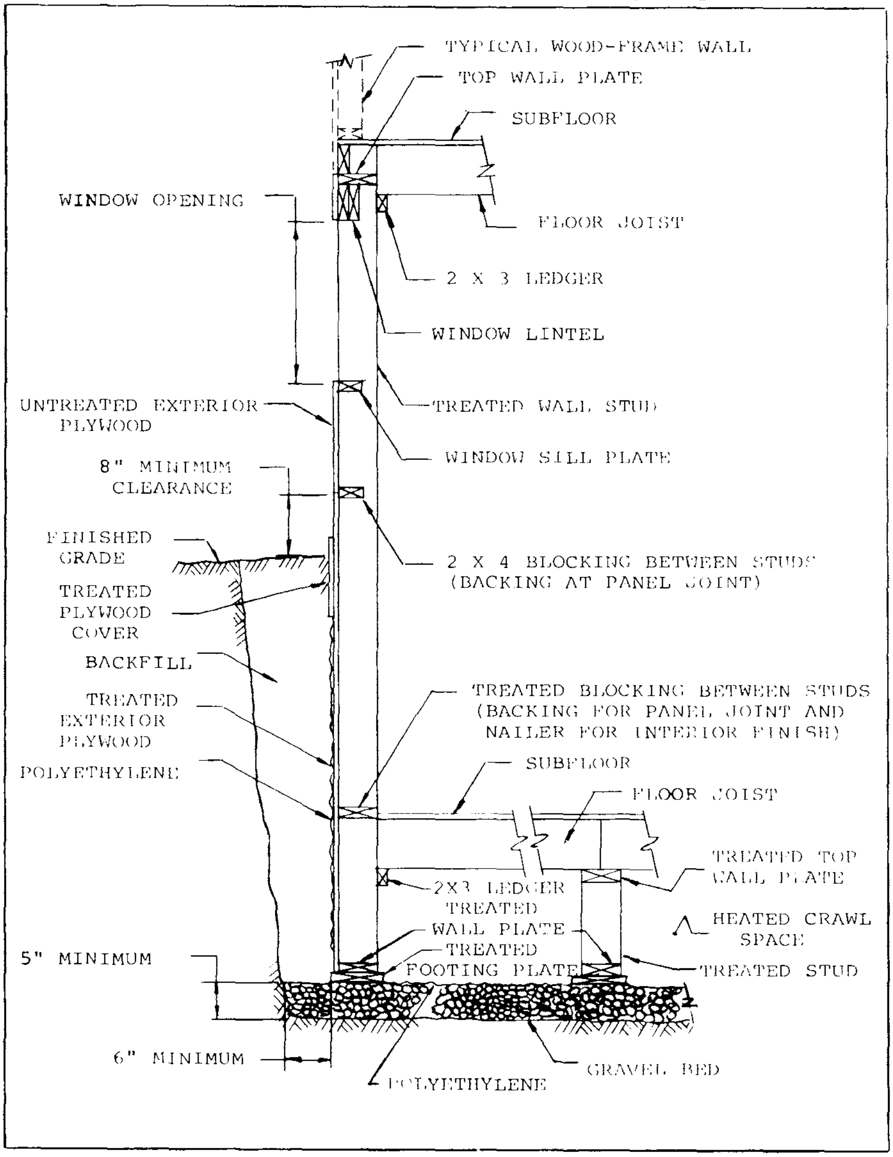
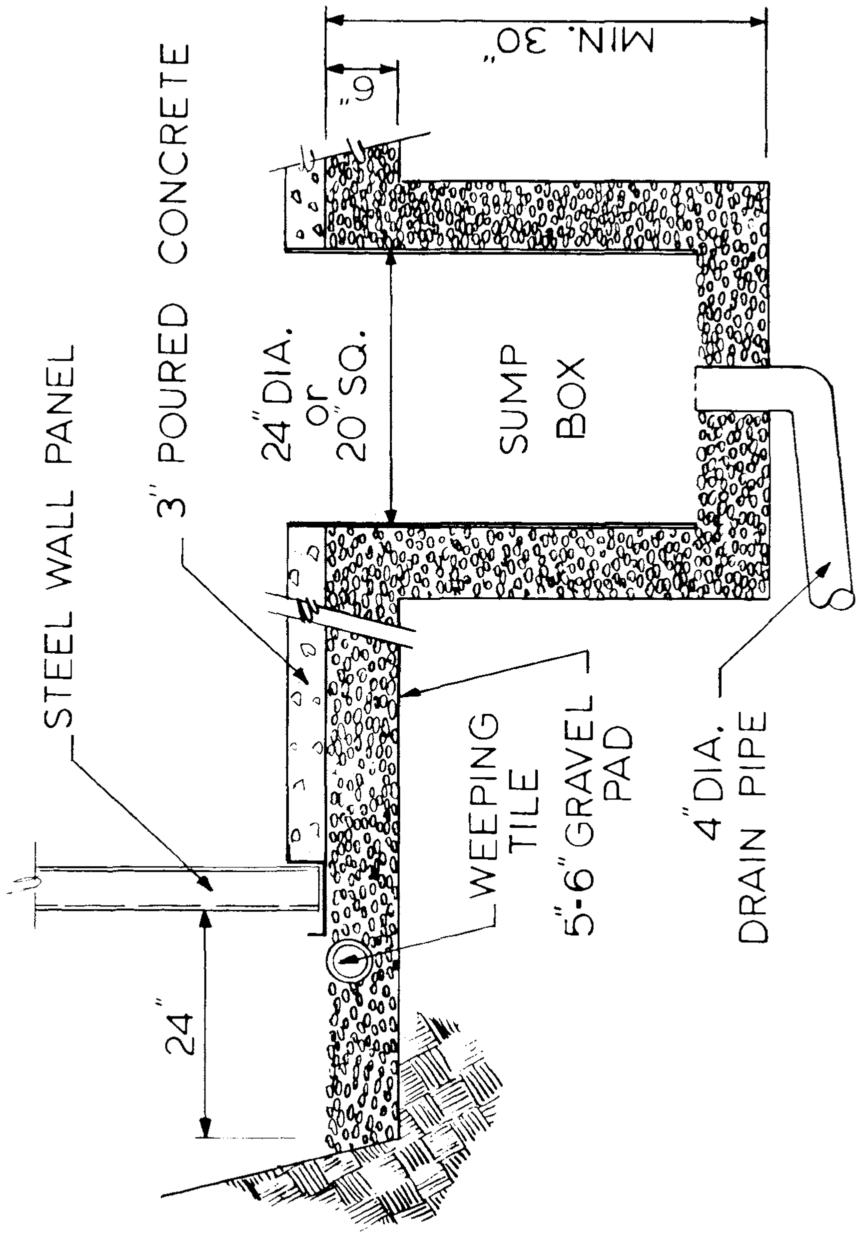


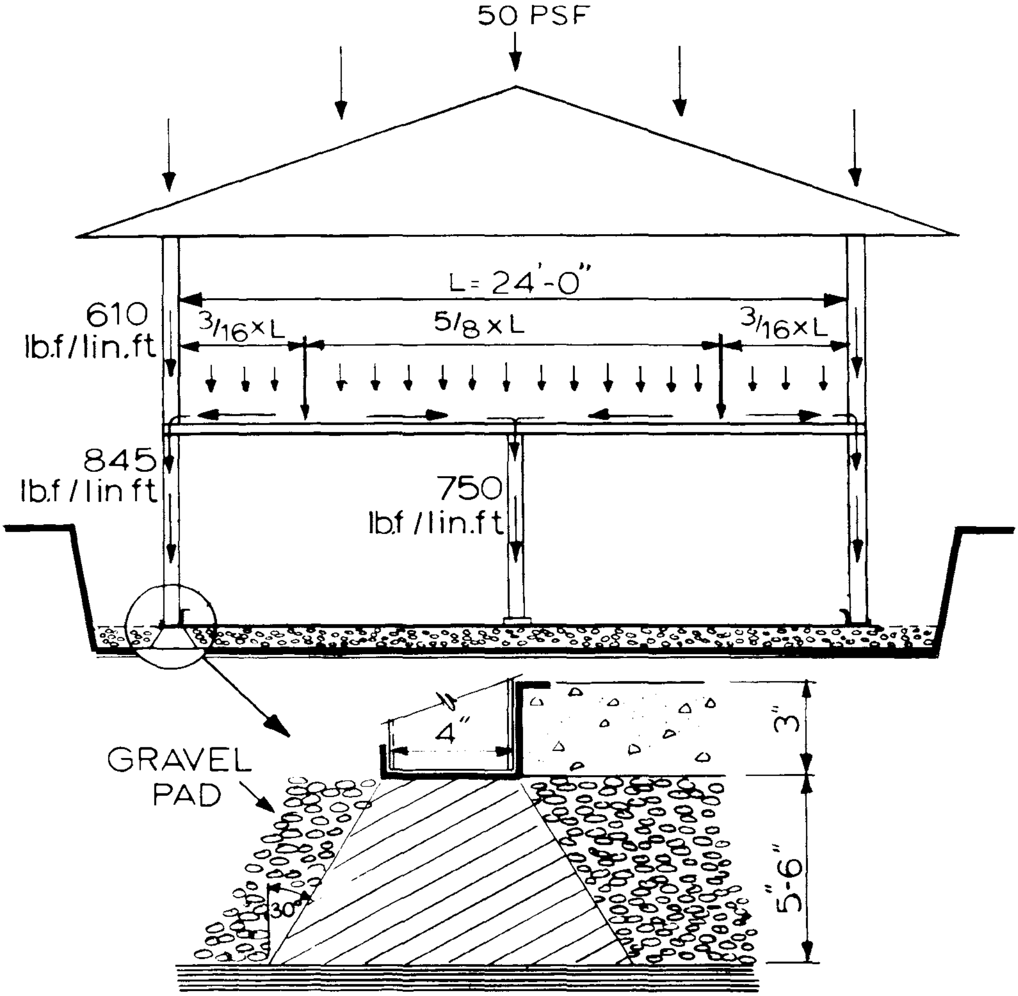
FIG.14

GRAVEL DRAINAGE PAD



LOAD TRANSFER DIAGRAM FIG. 15

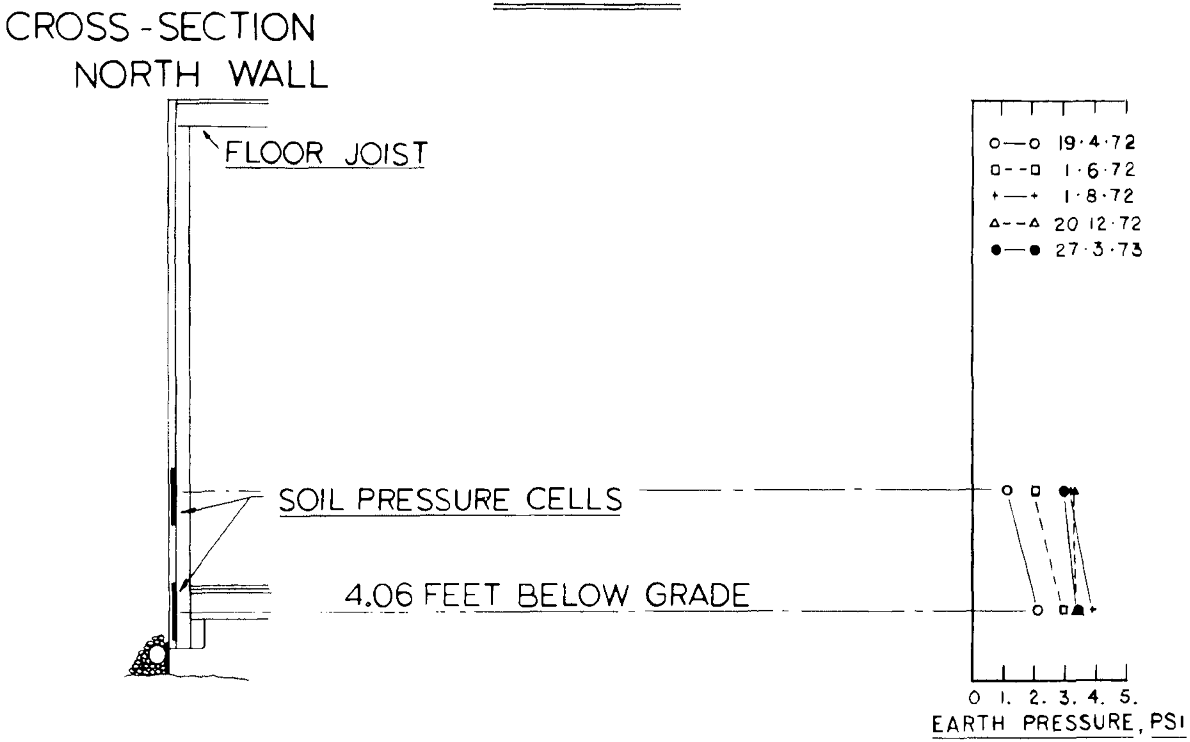
(MARK X)



WALL CROSS - SECTION AND PRESSURE MEASUREMENTS

MARK IX

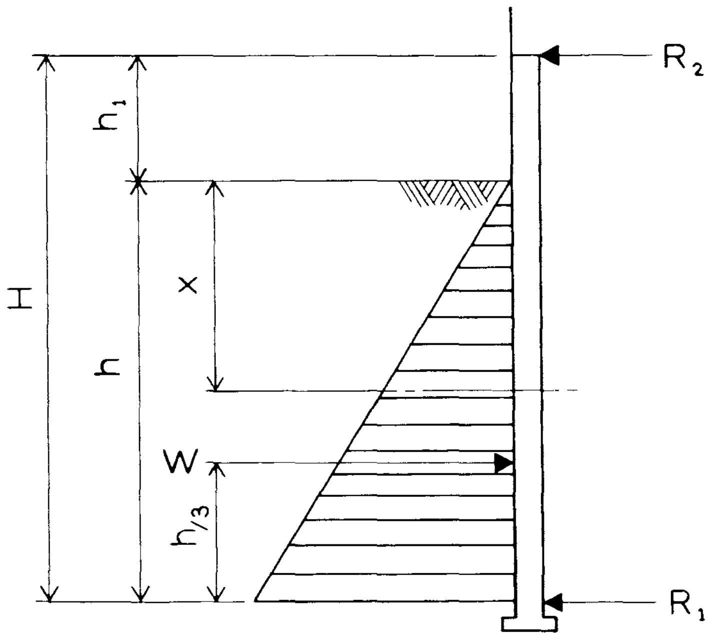
FIG. 16



NOTE: AT 4.06 FEET BELOW GRADE HALF HYDROSTATIC PRESSURE CORRESPONDS TO 0.85 PSI

FIG. 17

SOIL PRESSURE DIAGRAM



w = LATERAL SOIL PRESSURE, EQUIVALENT FLUID 30 PCF

W = TOTAL LATERAL LOAD = $\frac{wh^2}{2}$

h = DEPTH OF BACKFILL

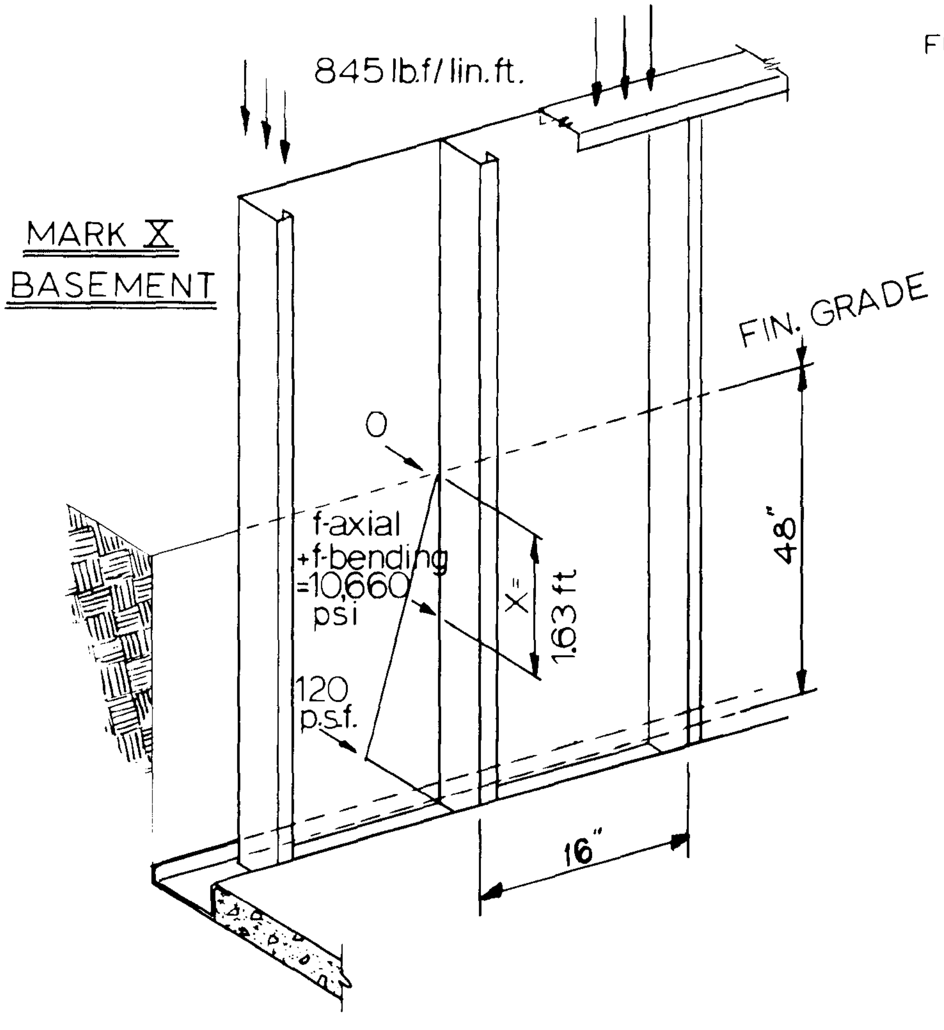
H = HEIGHT OF WALL

R_1 = MAXIMUM SHEAR = $W - \frac{Wh}{3H}$

x = POINT OF MAXIMUM MOMENT = $h\sqrt{\frac{h}{3H}}$

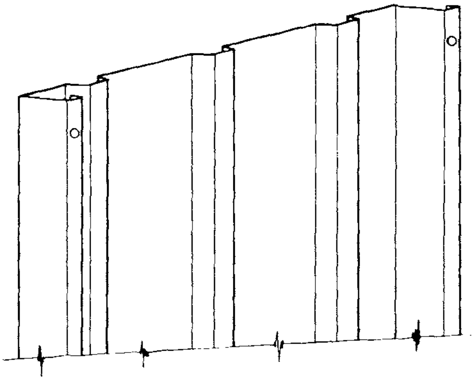
M = MAXIMUM MOMENT = $\frac{Wh}{3H}\left[h_1 + \frac{2h}{3}\sqrt{\frac{h}{3H}}\right]$

FIG.18

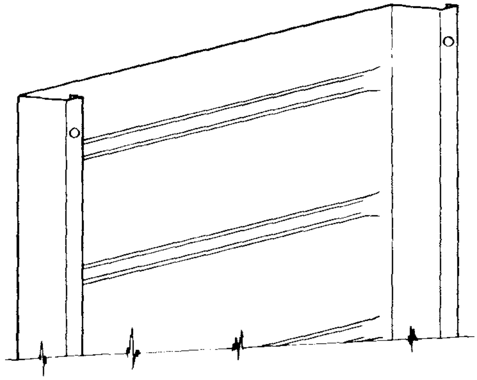

845 lb.f/lin.ft.
MARK X
BASEMENT
FIN. GRADE
O
f-axial
+f-bending
=10,660
psi
X=
1.63 ft
48"
120
p.s.f.
16"

PANEL STIFFENING

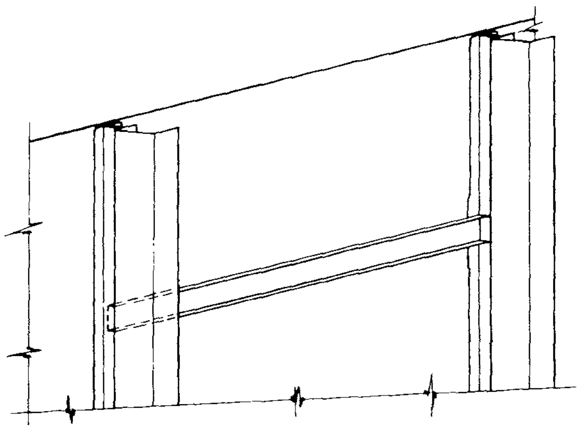
FIG. 19



19 a.



19 b.



19 c.

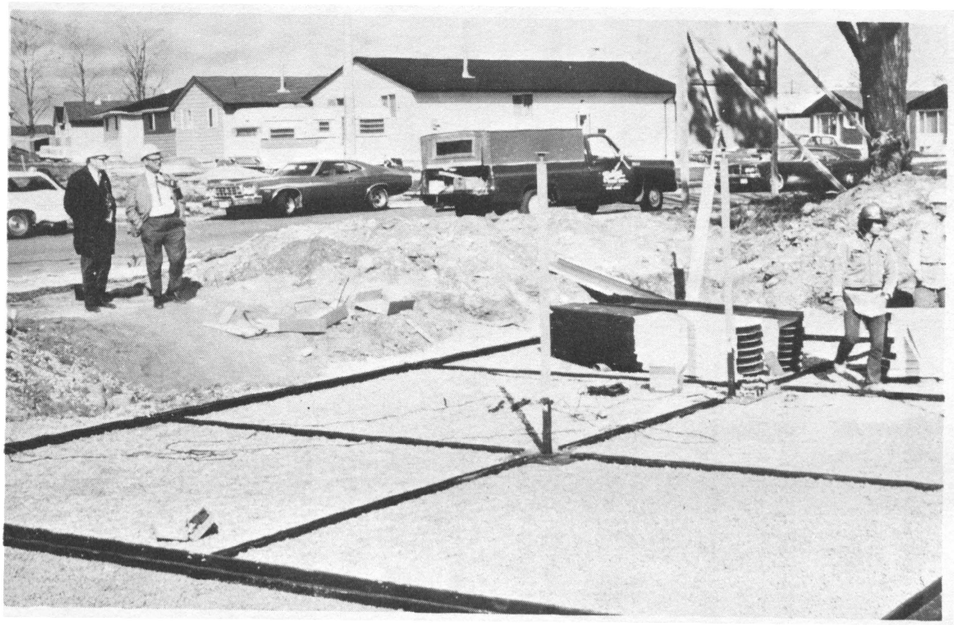


FIGURE 20 - MARK X FOUNDATION GRID

FIGURE 21 - MARK X CENTRE BEAM AND COLUMN ASSEMBLY

FIGURE 22 - MARK X COMPLETE BASEMENT

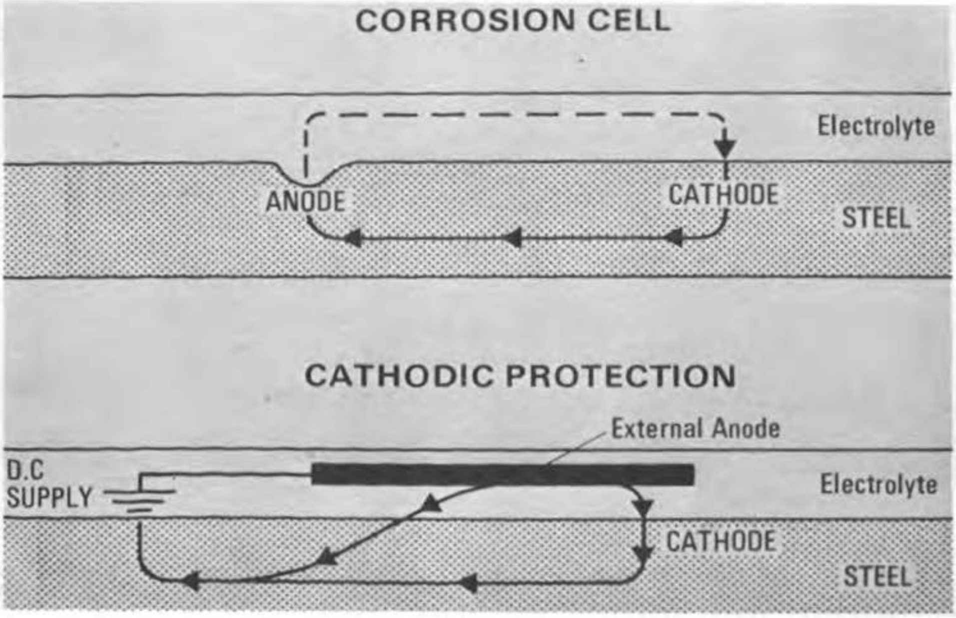
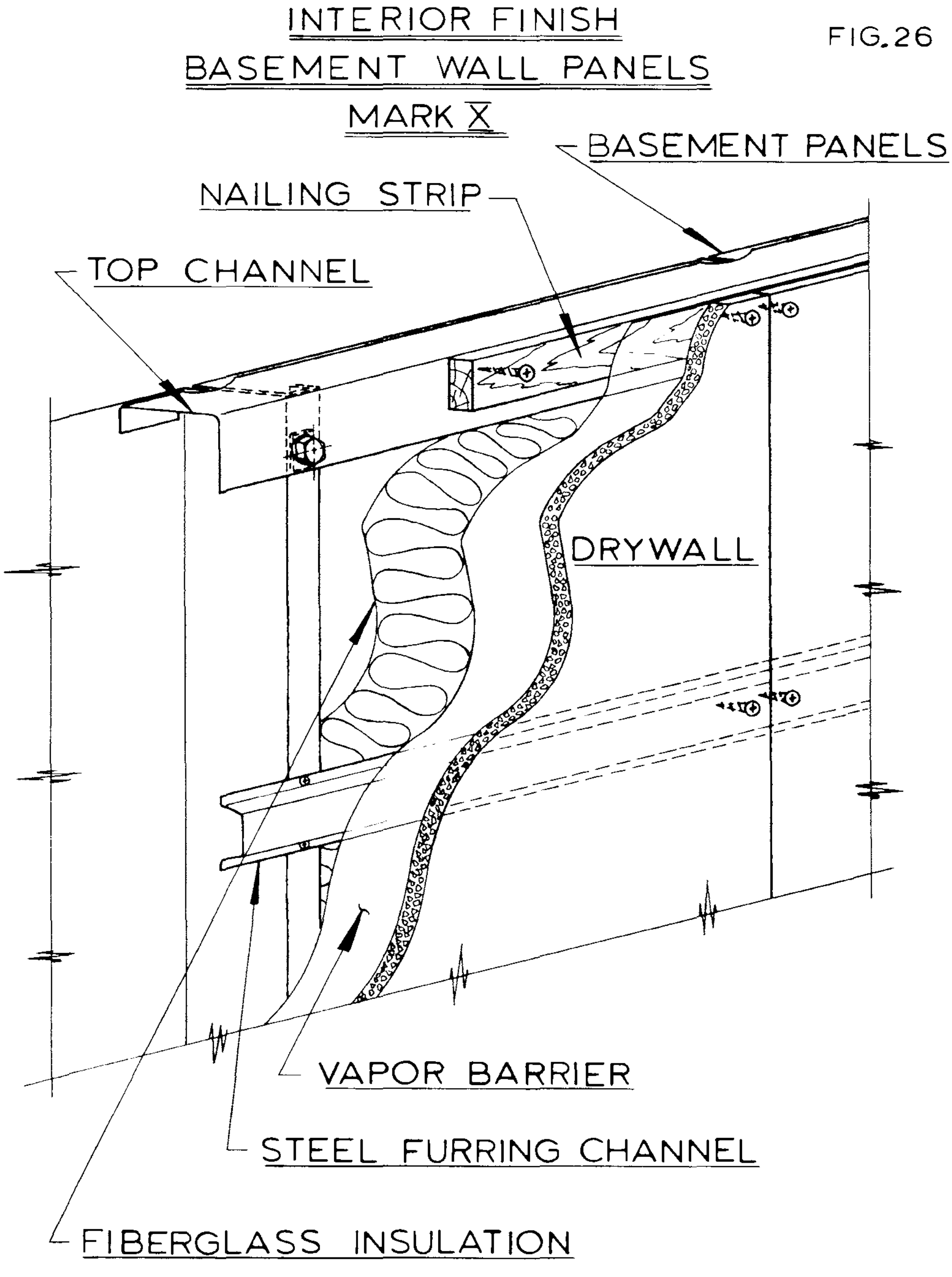


FIGURE 23 - PRINCIPLE OF ACTIVE CATHODIC PROTECTION

FIGURE 24 - MARK IX EXTERIOR BASEMENT INSULATION

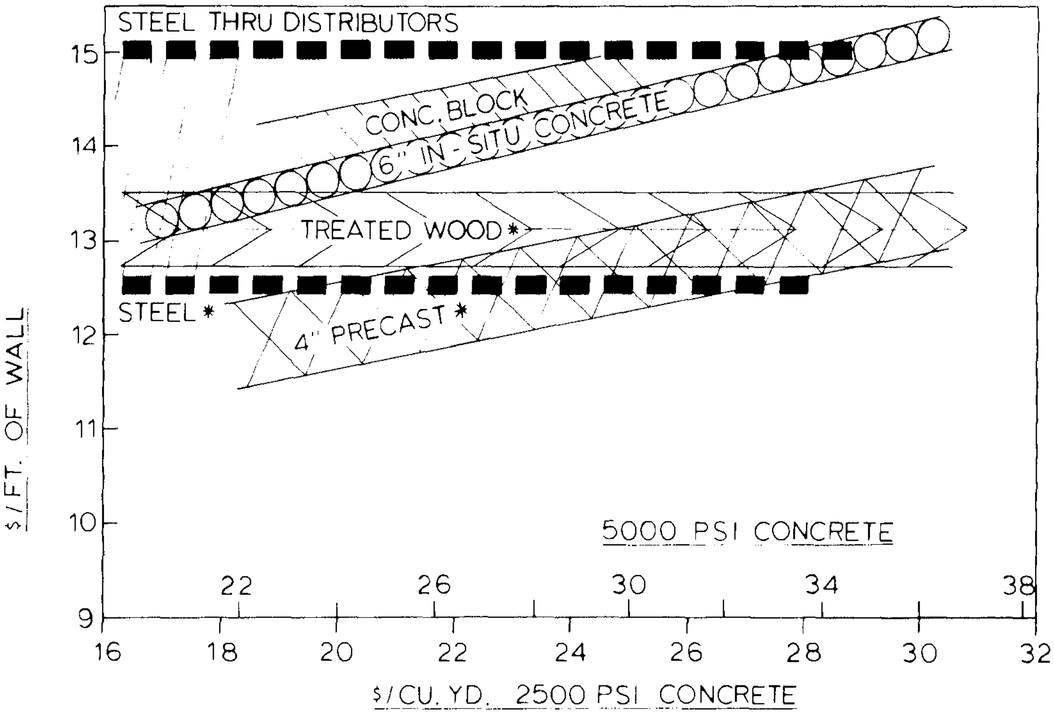
FIGURE 25 - MARK X SPRAY-ON URETHANE INSULATION


INTERIOR FINISH
BASEMENT WALL PANELS
MARK X
FIG. 26
BASEMENT PANELS
NAILING STRIP
TOP CHANNEL
DRYWALL
VAPOR BARRIER
STEEL FURRING CHANNEL
FIBERGLASS INSULATION

CANADIAN COST COMPARISON

RAISED BASEMENTS (4 FEET IN GROUND) AS OF FEBRUARY, 1974.

FIG. 27



* ASSUMPTION LARGE QUANTITY PRODUCTION.

REMARKS: PRICES INCLUDE ERECTION OF FOOTINGS AND BASEMENT WALLS INCL. INSULATION AND ROUGH DRYWALL. (COST OF EXCAVATION, GRAVEL PAD, DRAINAGE, BACKFILL AND BASEMENT FLOOR ARE NOT INCLUDED.)

IN THE CASE OF POURED AND PRECAST CONCRETE, THE COSTS OF TRANSPORTATION ARE BASED ON THE ASSUMPTION THAT THE PLANT IS LOCATED WITHIN APPROX. 20 MILES FROM SITE.

FIG 28

STEEL·BASEMENTS ADVANTAGES COMPARED TO OTHER SYSTEMS

	CONC BLOCK	POURED CONC	PRECAST CONC	WOOD
FAST ERECTION-1 DAY	●	●		
DRY SYSTEM-YEAR ROUND ERECTION	●	●		
LONG LIFE FOR BASEMENT SYSTEM WELL OVER 40 YEARS				●
LIGHT WEIGHT-LESS DEAD LOAD ON FOOTINGS EASY ERECTION & TRANSPORTATION	●	●	●	
NO CRANES OR OTHER SPECIAL EQUIPMENT			●	
NO TRADITIONAL FOOTINGS REQUIRED	●	●		
NO CRACKING	●	●		
NO LEAKAGE INTO FINISHED BASEMENT AREA WATER PENETRATING OUTER SKIN DRAINS WITHIN WALL ZONE	●	●	●	●
EASILY APPLIED INSULATION WITHIN STRUCTURAL WALL ZONE	●	●		
NO SEPARATE OR SPECIAL ELECTRICAL GROUNDING-TO WATER PIPE OR GROUNDING RODS	●	●	●	●
NO MUSTY ODOR OF DAMP CONCRETE OR MASONARY	●	●	●	
NO PARGING	●			
NO SITE APPLIED BITUMEN DAMPPROOFING	●	●		
NO ON-SITE SEALING CAULKING OR FILLING		●	●	
NO SITE APPLIED POLYETHYLENE WATERPROOFING				●
NO SITE-APPLIED ABOVE GROUND FINISH	●	●		●
POSSIBILITY OF SIMPLIFIED ELECTRIC WIRING-ELIMINATION OF GROUND WIRE	●	●	●	●
POSSIBILITY OF FULL HEIGHT PANELS ERECTION OF BASEMENT AND UPPER LEVEL WALLS IN ONE OPERATION	●	●	●	●
POSSIBILITY OF REMOVAL AND RE-USE OF BASEMENT	●	●		

ESTIMATED MARKET POTENTIAL
FOR RESIDENTIAL BASEMENTS
IN CANADA AND THE UNITED STATES

FIG. 29

CANADA

	IN %	IN NUMBER OF UNITS
SINGLE DETACHED HOUSES WITH FULL BASEMENTS WITH PARTIAL BASEMENT OR CRAWL	100% 87% 10%	94,500
SINGLE DETACHED AND DUPLEX WITH FULL BASEMENT WITH PARTIAL BASEMENT OR CRAWL	100% 85% 12%	10,800
ROW HOUSING WITH FULL BASEMENT WILL PARTIAL BASEMENT OR CRAWL	100% 80% 11%	18,900
WALK-UP APARTMENTS AND OTHERS (UP TO 3-1/2 STORIES) WITH FULL BASEMENT WITH PARTIAL BASEMENT OR CRAWL	100% 71% 18%	58,400

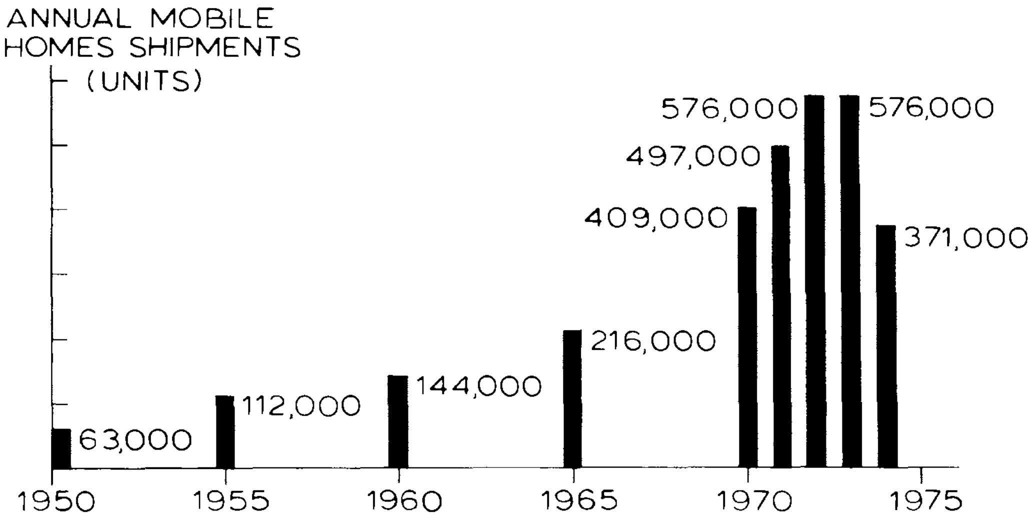
UNITED STATES

SINGLE DETACHED HOUSES	100%	1,226,000
WITH FULL BASEMENT	34.1%	418,000
WITH PARTIAL BASEMENT	8.3%	102,000

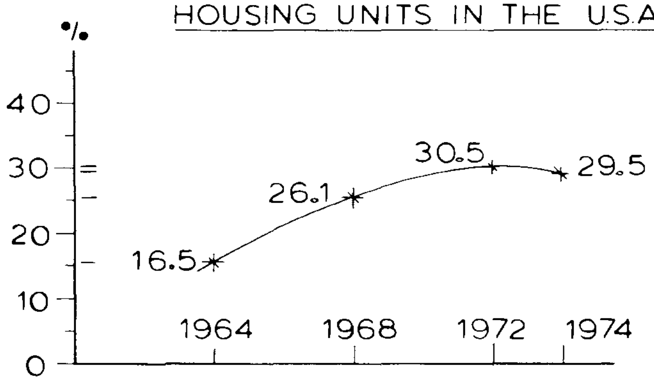
MULTI-FAMILY DETACHED HOUSES - IT IS ESTIMATED THAT BETWEEN 10% AND 15% OF MULTI-FAMILY LOW-RISE HOUSES (DUPLEXES, TOWNHOUSES, ETC.) HAVE BASEMENTS.

MOBILE HOMES MARKET IN THE UNITED STATES

FIG.30

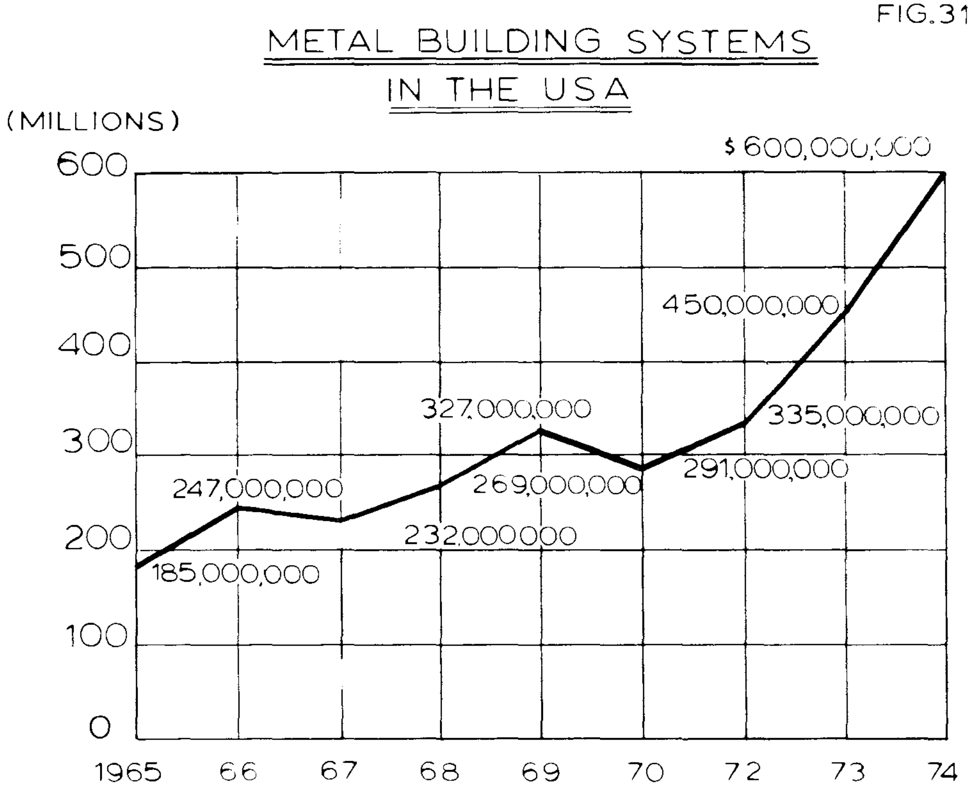


PRODUCTION OF MOBILE HOMES AS A % OF THE TOTAL*SINGLE FAMILY HOUSING UNITS IN THE U.S.A.



*"TOTAL" = MOBILE HOME PRODUCTION PLUS SINGLE FAMILY PRIVATE HOUSING STARTS

FIG. 31



SALES FIGURES FOR THE METAL BUILDING INDUSTRY REPRESENT ONLY THE VALUE OF THE METAL BUILDING COMPONENTS. THE METAL BUILDING SYSTEM, ON AN AVERAGE, REPRESENTS ABOUT 20% OF THE TOTAL CONSTRUCTION PROJECT. THE 1973 SALES REPRESENT APPROXIMATELY $3 BILLION OF IN PLACE CONSTRUCTION.